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ENERGY EFFICIENCY PREDICTION MODEL OF HEAVY-DUTY ELECTRIC VEHICLES USING NUMERICAL SIMULATION

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ABSTRACT–This paper is a study on energy efficiency prediction model of heavy-duty electric vehicles using numerical simulation. Because the current energy consumption efficiency evaluation method for electric vehicles has limitations in terms of manpower, resources, and time required, therefore a simulation model development to predict electric vehicle energy consumption efficiency is needed. Furthermore, research on heavy-duty electric vehicles is relatively insufficient compared to light-duty electric vehicles, and the need of research on heavy-duty electric vehicles is increasing. Therefore, this study develops an energy efficiency prediction model for heavy-duty electric vehicles and verifies it with the experimental results. Based on this, the applicability of the simulation method using the developed prediction model to the current energy efficiency evaluation management system for heavy-duty electric vehicles was reviewed. To verify the accuracy of the simulation model, the dynamometer test results were compared to simulation results, and the UDS protocol was used to acquire internal data for heavy-duty electric vehicles. Reliability of simulation model was secured by comparing data such as motor speed, battery voltage/current, state of charge and total driving distance of the test vehicles with data from the dynamometer experiment and the simulation model.

KEY WORDS : Heavy-duty electric vehicles, Energy efficiency, Numerical simulation, Multi cycle test, State of charge

NOMENCLATURE

$F_{\mathrm{x,y,f,ax}}$	: front axis load (N)
$F_{\mathrm{x,y,r,ax}}$	: rear axis load (N)
α_U	: inclination (rad)
α_V	: vehicle acceleration (m/s^2)
$F_{\mathrm{v,lift,f}}$	: lift force of front tire (N)
$F_{\mathrm{v,lift,r}}$	: lift force of rear tire (N)
$\mathrm{m}_{\mathrm{v,lift,r}}$	: vehicle weight (kg)
$F_{total,\mathrm{driving}}$	: total driving force (N)
F_{accel}	: acceleration & deceleration force (N)
$F_{\mathrm{v,air}}$	: aerodynamic drag force (N)
$F_{v,rr}$	: tire rolling resistance force (N)
F_{incl}	: inclination force (N)
$F_{f,pt}$	: friction loss in powertrain lines (N)
c_w	: aerodynamic drag coefficient
A_v	: frontal area (m^2)
ρ_{air}	: air density (kg/m^2)
$v_{U,V,rel}$	: relative velocity (km/h)
L	: vertical load acted on wheel (lbs)
P	: inflation pressure of the tire (psi)
V	: vehicle velocity (mph)
M_B	: braking torque (kgf·m)
p_B	: braking pressure (Pa)
A_B	: brake piston surface (m^2)
η_B	: efficiency
μ_B	: friction coefficient
r_B	: effective friction radius (m)
c_B	: specific brake factor
η_f	: final gear efficiency
η_g	: gear box efficiency
r_f	: final gear ratio
r_g	: gear box ratio
USA	: United States of America
EU	: European Union
UDS	: unified diagnostic services
SCT	: single cycle test
MCT	: multi cycle test
SMCT	: short multi cycle test
UDDS	: urban dynamometer driving schedule
HWFET	: highway fuel economy test
HWVC	: world harmonized vehicle cycle
CSC	: constant speed cycle
SOC	: state of charge
SAE	: society of automotive engineers
BEV	: battery electric vehicle

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